Impact Craters

Lesson 1 – Impact Crater Morphology

Impact Crater Morphology

Grade Level: 7-12

Time Needed: 1-2 class periods

Objectives:
- Use the scientific method to generate a proposed explanation, construct an experiment to test a hypothesis, make predictions, gather data, and interpret results for the question presented.
- Comparison of crater morphologies.
- Describe the factors that affect crater morphologies.

Arizona State Standards:
- 1SC-P2. Compare observations of the real world to observations of a constructed model. PO 1. Assess the capability of a model to represent a “real world” scenario.
- 6SC-P1. Explain prominent scientific theories of the origin of the universe, the solar system, and life forms. PO 4. Relate physical laws to processes explained by prominent scientific theories of the origin of the universe, the solar system, and life forms.
- 6SC-E2. Describe common objects in the solar system and explain their relationships. PO 1. Describe common objects in the solar system.

Background:

In this lesson students will explore impact cratering processes and the factors that affect impact crater **morphology**. As discussed in the introduction to this module, impact craters are divided into three main categories based on their diameter and morphology (Overhead 1). **Simple craters** are so named because they are the smallest craters, commonly less than 5 km (3 miles) in diameter, and display a bowl shaped depression (Overheads 2 and 3). Meteor Crater (Overhead 4) is a simple crater and, at only 1 km diameter, a very small crater compared to most of the craters visible on the moon (Overhead 5). **Complex craters** are larger, 5km to 50 km (3 to 31 miles) in diameter. They have a central peak caused by the elastic rebound of material as a result of the shock waves caused by impact (Overheads 6 and 7). The largest type of impact crater is a **multi-ring basin**. These craters typically have diameters larger than 50 km (30 miles) and contain more than one concentric ring of low ridges or hills protruding above the floor inside the craters dominant rim. Tiny impact craters, called "zap pits" are produced by small, high velocity particles and are common on the exposed faces of lunar rocks (Overhead 8a). They also develop on the Space Shuttle, especially the windows, when debris hits the spacecraft.

Impact craters look quite similar to craters formed at nuclear test sites and those created from volcanic eruptions (Overhead 9). Volcanic craters commonly have associated lava flows and pyroclastic deposits, while nuclear test sites, although remarkably similar in structure to impact craters, will contain nuclear fall out material. Impact sites may show no evidence of the original impactor. When a meteor hits the surface of a planet it is obliterated by the tremendous force released during impact. All that remains is a depression in the surface, structurally deformed rock units, and often an **ejecta** blanket.

Meteors are parts of asteroids or comets that have entered a planet's atmosphere. Most are small particles, dust or sand sized, and these tiny bits are what we see during meteor showers interacting with the Earth's atmosphere. Most of the meteors that enter the atmosphere burn up before they reach the surface of a planet because they are so small. However, there are meteors that have the potential to impact a planet. Once landed, the rock is called a **meteorite**. A planet's atmosphere has little effect on larger **impactors**. The bodies are large enough and traveling at such high speeds that the few seconds spent moving through an atmosphere has little effect on its mass or velocity.

The size of an impact crater is primarily dependent upon the velocity of the impacting object, secondarily on its mass. Use the interactive Excel file provided (cratereq.xls) to see the relationship between meteor size and diameter of the resulting impact crater with user-defined variables. There are also two tables provided in the trunk illustrating the consequences and of impact. Impact crater size also depends on the amount of kinetic energy (KE) an impactor possesses. Kinetic energy, energy in motion, is described as:

$$\mathbf{KE = \tfrac{1}{2}(mv^2)}$$

Where **m** = mass of impactor (kilograms) and **v** = velocity of impactor (meters/second)

Lesson overview:

- Students will use the scientific method to determine the factors affecting impact crater morphology and present their results to the class.
- They will have 20 minutes to design an experiment to test their hypothesis.
- They will document their experiment on whiteboards.
- Students will clean up their lab station and return materials to their proper place.

Materials:

- Plastic tubs (provided)
- Flour or different colors of sand
- Cocoa
- Newspaper
- Whiteboards and dry erase markers
- Stopwatches
- Rulers
- Aprons
- Tape measures
- Sieves
- Round objects of different sizes and masses (wooden beads, ball bearings, marbles, etc…) (provided)

Instruction:

- Show students an image of Meteor Crater in Arizona (Overhead 4).

- Ask students to describe what they are seeing and discuss this as a class.
- Then have students formulate questions about the crater they are observing. The first thing scientists do is observe an object or phenomenon and ask questions about it. For example:
  - **Why is the crater shaped the way it is?** This is a result of the mass, velocity, impact angle, and KE of the impacting object and also the geology of the bedrock.
  - **What determines the size of a crater?** The size and velocity of impactor.
  - **What created the crater?** A meteor, a volcanic eruption, a nuclear test bomb, manmade, etc…
  - **Where is the material that was in the hole?** It has been obliterated and thrown out of the crater as ejecta.
- Have the students write these questions on the board under the heading. QUESTIONS.
- In this lesson students will explore the question, " What factors affect the shape and size, i.e. morphology, of impact craters?" Have students come up with a hypothesis similar to this one and write it on the board under HYPOTHESIS.
- Divide students into groups of 3-4.
- Have each group write the question the class is exploring at the top of their whiteboard then have them form a hypothesis to explain their observations.
- Now the students are ready to apply the scientific method. They should do this before getting their materials. I like to use the following format:

If = proposed explanation or hypothesis
And = Test
Then = Prediction
And/But = Actual outcome or result
Therefore = Conclusion - hypothesis supported or not supported

The Scientific Method!

IF: the size of an impactor effects the size of the resulting impact crater
AND: we drop a large and small impactor into our tub
THEN: the small impactor will create a smaller crater than the larger impactor
AND/BUT: indeed the smaller impactor did create a smaller crater than the larger impactor
THEREFORE: our hypothesis is supported

Procedure:

- Fill the tubs with about 3 to 4 inches of flour and sift a layer of cocoa over the top.
- Place one tub at each lab group table.
- All other materials will be on a table at front of room.
- Groups take the materials they will use to conduct their experiments.
- Newspaper should be put on the table and floor surrounding the tub (see attached images).

- Students will use the materials available to develop a test for their hypothesis.

For example: If the students are testing a hypothesis such as “meteor size affects crater size”, they might try dropping round objects of different sizes in the pan of flour and observe the differences in size. Then based on their observations they can document results on their whiteboard. They may also include graphs, tables, drawings, and any other relevant information illustrating their results. Finally, students will make conclusions based on their results and state whether their hypothesis was supported or not.

Closure and Assessment:

- Bring groups together to discuss their experiments and results. Display the Student Assessment Questions as a guide.
- Have the groups go around the room and visit each lab table. This gives each group the opportunity to explain and show the rest of the class how they went about designing their experiment and gathering results.
- After the groups have discussed their experiments, explain that there are several types of crater morphologies, simple, complex, and multi-ring basins, all dependent on the characteristics of an impactor.
- Show Overheads 2 and 6 to explain the difference between simple and complex crater formation processes.
- Then show Overhead 3, a simple crater with cross section and Overhead 7, a complex crater with cross section. Ask students what may cause the different shapes. For example some have central peaks while others are bowl shaped.
- Display Overhead 1 to show the different parts of craters.
- To close, return to the topic of Meteor Crater. Tell students that it is indeed an impact crater about 1 kilometer (3/4 mile) in diameter, 180 meters (600 feet) deep, and was created by a meteor about 30 meters (100 feet) across. Ask them if they would call Meteor Crater a BIG crater. Then display Overhead 8, a comparison of Meteor Crater and craters on the Moon. Discuss as a class.

Vocabulary:
Impact crater, morphology, ejecta, impactor, simple crater, complex crater, multi-ring basin, kinetic energy, meteor, meteorite

References and Resources:

* Interactive Excel file (cratereq.xls), calculates crater diameter with user defined variables. (provided)

* **Exploring Meteorite Mysteries, Lesson 7—Crater Hunters**, NASA EG-1997-08-104-HQ. (provided)

* **Exploring the Moon, A Teachers Guide with Activities, Impact Craters**, NASA EG-1997-10-116-HQ. (provided)

* **Modeling Meteorite Impact Craters**, Roddy, D., USGS, 2001.

* **Impact Craters**, Hawaii Space Grant College, Hawaii Institute of Geophysics and Planetology, University of Hawaii, 1996.

Images of impact crater lesson taught in the classroom

Students discuss their methodology.

Simple crater with ejecta rays.

Craters formed in different substrates.

Student Assessment Questions:

1. How does the velocity of an impactor affect the size of impact craters?

2. How might time be related to the number of craters in a particular region?

3. Why do we not see as many craters on Earth as on other planetary surfaces?

4. What would happen to these craters if a volcano erupted near them?

5. Why are there fewer impacts taking place on planetary surfaces today?

6. If you could do the experiment again, how would you do it different?

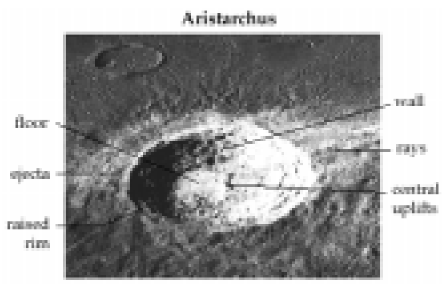
7. Did you enjoy learning about craters this way, or would you prefer to learn another way?

8. What type of craters did you create: simple, complex, or multi-ring?

9. Name one difference between your model and a real world impact crater.

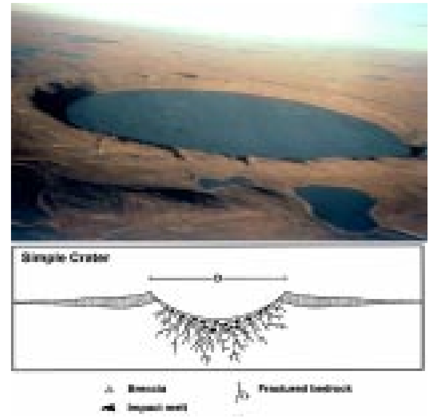
OVERHEADS

PARTS OF A CRATER



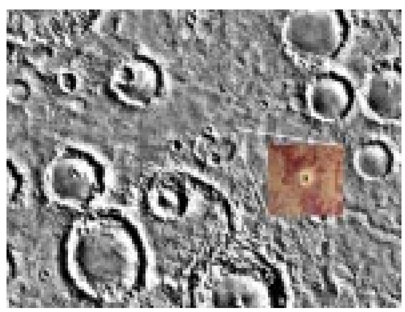
Overhead 1. The parts of a crater.

Overhead 2. Simple crater formation.

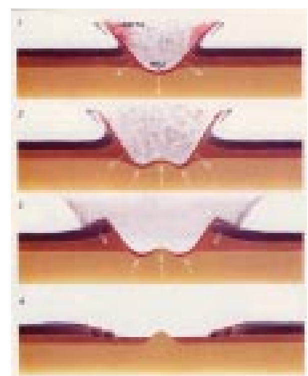


Overhead 3. Simple Crater morphology. Lonar Crater, India.

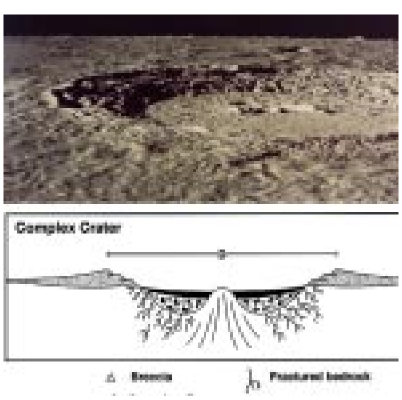
Overhead 4. Simple crater. Meteor Crater, AZ.



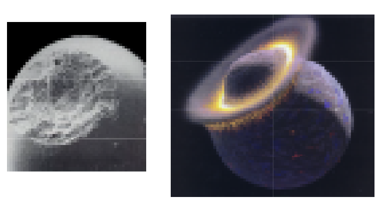
Overhead 5. Comparison of the size of Meteor Crater to the number and sizes of craters on Mars.



Overhead 6. Complex crater formation.



Overhead 7. Complex crater morphology. Copernicus crater, Moon.



Overhead 8. Range of sizes of craters formed. Zap pits (left), the smallest, are microns across. Right, Mars-sized object hitting Earth that formed the moon.

Overhead 9. Meteor Crater (top), nuclear explosion crater (bottom).